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CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE, E. L. MARK, DIRECTOR, No. XCII.

A CONTRIBUTION TO THE STUDY OF INDIVIDUAL VARIATION IN THE WINGS OF LEPIDOPTERA.

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Presented by E. L. Mark, April 13, 1898.

I. Statement of the Problems.

This paper gives the results of an attempt to find, in a particular species, answers to the following questions: —

1. Is a part, developed in any given species in an extraordinary manner as compared with the development of the corresponding part in other allied species, more variable than parts which exhibit less specific peculiarity?

2. Which sex is the more variable?

The first question is raised to test, by quantitative methods, the law of variation enunciated by Darwin (Origin of Species, 6th edition, §§ 220, 221). It is unnecessary to argue the importance of tests of this kind. From data offered by others we may obtain quantitative expressions of certain cases. Thus, while in nearly all groups of Mammals except the sloths the number of cervical vertebræ is 7, it is a familiar fact that in this aberrant group the number varies from 6 to 10. Bateson ('94) gives the following data obtained from fifty-seven individuals belonging to the genus Bradypus: —

No. of Cervical Vertebræ	8	9	10
No. of Cases	6	46	5

Mean, 8.98+. Average Deviation from Mean, 0.21—.

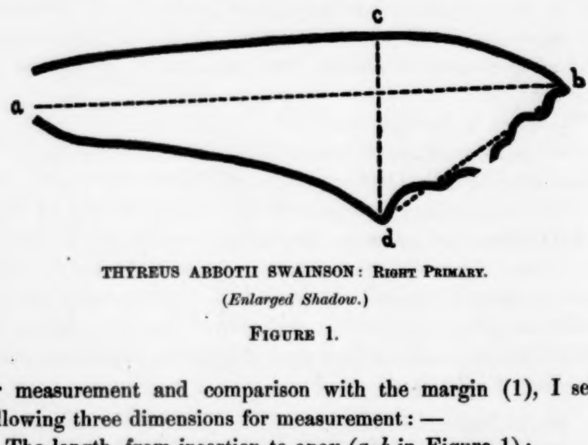
With regard to the characteristic under consideration, the Average Deviation for other Mammals will be 0.00+. The comparison of these two Average Deviations gives us a measure of the greater variability of

the group with the exceptional structure. Other contributions to this law from other groups of animals are needed.

The second question bears upon the significance of sexual dimorphism. The quantitative studies of Davenport and Bullard ('96) upon the glands in the fore legs of pigs show the variability of the males to exceed that of the females by 2.5% ; while, on the contrary, Pearson ('97) shows that women are in general slightly more variable than men, — exhibiting the greater degree of variability in eleven out of a total of seventeen characters under consideration.

II. Method.

The species upon which I have worked is the moth *Thyreus abbotii* Swainson, one of the common Sphingidæ of Eastern North America. It differs from its allies most notably in that the outer margins of the primaries are excessively irregular and extraordinarily long, as compared with other dimensions of the wings. I have tried to find an answer to the question, Is this extraordinary outer margin more variable than other more ordinary characters of the same wing?



THYREUS ABBOTII SWAINSON: Right Primary.

(*Enlarged Shadow.*)

Figure 1.

For measurement and comparison with the margin (1), I selected the following three dimensions for measurement: —

(2) The length, from insertion to apex (*a–b* in Figure 1);

(3) The greatest breadth, — the perpendicular distance of the posterior protuberance of the outer third of the wing from the costa (*c–d*);

(4) The length of an imaginary straight line drawn between the extremities of the sinuous margin, — that is, from apex to posterior protuberance (*b–d*).

The three dimensions defined above were measured with a pair of sharp-pointed dividers with screw adjustment, and a scale graduated in millimetres. To eliminate error, precautions were taken which will shortly be described.

The measurement of the margin required special apparatus; and after a number of experiments I succeeded in constructing an inexpensive and efficient projecting instrument, as follows. A vertical wooden post, about eight inches high, was firmly fixed to one end of a solid base-block. On the top of the post was placed a binding-screw, which held a horizontal brass rod, to the extremity of which was fastened a miniature incandescent electric lamp of two candle-power. The electrical connections were formed respectively by the carrying-rod and a flexible spiral of fine wire, the latter also leading to a binding-screw. A one-point switch, situated upon the base-block, served to open and close the circuit. To the lower portion of the post, and projecting horizontally beyond the end of the base-block, was fixed an arm carrying still another binding-screw, holding a vertical steel rod, in such a way as to afford a considerable range of adjustment up and down. To the upper extremity of this rod was fastened a firm "stage" of cork, in which the pin bearing a specimen might be inserted. A graduated scale upon the post permitted an approximate determination of adjustment in height.

The function of this instrument was to project an enlarged shadow of the wing upon a sheet of paper placed upon the table, so that the outline might be traced with a pencil. When connected with three cells of a "Samson" open-circuit battery, in a darkened room, it did its work admirably. The shadow produced was sharp and clear, and could be drawn quite as accurately as the image formed by an Abbé camera.

Of course it was not easy to gauge the enlargement (and consequent distortion) of the image accurately; but this was unneccessary. The error being almost exactly the same for the sinuous line and its "chord," (as I have termed the straight line *b–d*, Figure 1, drawn between its extremities,) it was only necessary to find the ratio between the two, — the actual length of the "chord" being afterward measured directly from the specimen, with the aid of the dividers already referred to. The projected "chord" was measured with a metric ruler, and the sinuous line with an "Entfernungsmesser," or map-measurer.*

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* The map-measurer is an instrument provided with a small wheel, which is made to roll along the line to be measured, and a recording dial, registering in centimetres the distance covered. Instruments of this sort are small and rather cheap, and may usually be obtained from dealers in draughtsmen's supplies.

In reading the adjustment of the dividers, the distance was laid off four times along a ruled line, and the result was divided by four. This served to diminish errors in the use of the scale. The dividers were always returned to the starting point as a test for change of adjustment, but no change ever appeared. The error introduced in this process was probably less than one per cent.

The "Entfernungsmesser," as I have said, registers in centimetres. To obtain an accurate reading, it was run over each line a number of times (sometimes fifteen or twenty, if error were suspected), and the reading for ten trips was taken direct, with the substitution of millimetres for the centimetres of the reading. This method was laborious, but accurate. By actual test the average error was found to be less than one per cent.

III. Results.

In the following tables, AD stands for Average Deviation of the measurements from the mean of all; CV for the Coefficient of Variation, which is the average deviation divided by the mean.

	Wing Length (Fig. 1, *a–b*).	Wing Breadth (Fig. 1, *c–d*).	Chord (Fig. 1, *b–d*).	Margin.
Total of measurements of 31 males	mm. 929.6	mm. 333.2	mm. 450.3	mm. 529.7
Mean	29.9	10.7	14.5	17.1
Total of deviations	20.3	10.1	14.0	24.2
AD (sexual)	0.654	0.322	0.451	0.780
CV (sexual)	0.022	0.030	0.031	0.046
Total of measurements of 19 females	598.2	213.6	281.2	340.1
Mean	31.5	11.2	14.8	17.9
Total of deviations	13.9	7.6	11.0	14.4
AD (sexual)	0.731	0.400	0.578	0.754
CV (sexual)	0.023	0.036	0.039	0.042
Total of measurements of 50 specimens, both sexes	1527.8	546.8	731.5	869.8
Mean	30.5	10.9	14.6	17.4
Total of deviations	45.3	21.0	26.1	36.0
AD of species	0.906	0.420	0.522	0.720
CV of species	0.030	0.039	0.036	0.041
Curves of distribution of individual measurements	Fig. 2	Fig. 3	Fig. 4	Fig. 5

The results may be summarized thus: —

	31 Males.		19 Females.		50 Both Sexes.	
	AD	CV	AD	CV	AD	CV
Wing length	.654	.022	.731	.023	.906	.030
Wing breadth	.322	.030	.400	.036	.420	.039
Length of chord	.451	031	.578	.039	.522	.036
Length of sinuous margin . . .	.780	.046	.754	.042	.720	.041

From this table it appears that the length of the sinuous margin has a greater Coefficient of Variability than any of the other dimensions measured, being

In the male	48%	greater than CV of chord.
In the female	8%	" " "
In both sexes taken together	14%	" " "

Comparing the Average Deviations of the two dimensions, we find a still greater proportional difference.

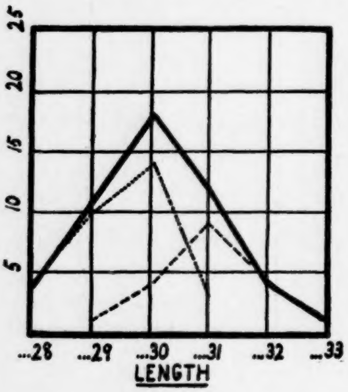

Figure 2.

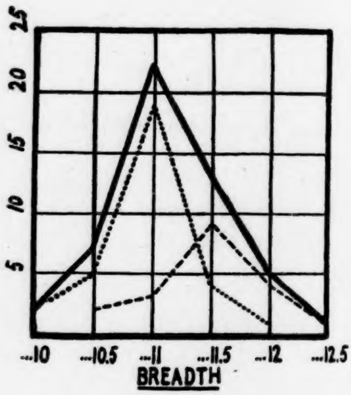

Figure 3.

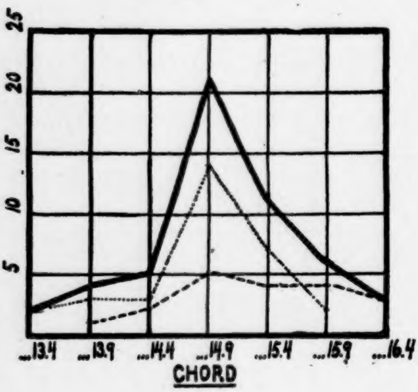

Figure 4.

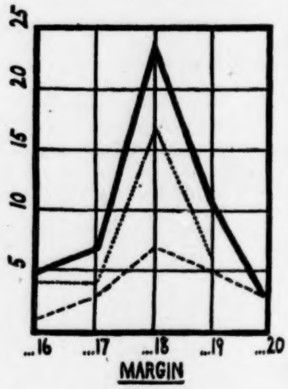

Figure 5.

Diagrams illustrating Individual Variation in Thyreus abbotii.

Numbers of specimens plotted as ordinates; measurements (in millimetres) as abscissæ. The numbers appended to the ordinates indicate the maximum measurements in the respective groups.

——— Both Sexes; ············ Males; - - - - - - - - Females.

Comparing the results obtained from the males with those from the females, we find the greater variability in the latter sex, except in the case of the sinuous margin. This does not accord with the generally accepted theory of the variability of the sexes, but if there were sufficient statistical data it would probably appear as a rather common phenomenon among the Lepidoptera; for dimorphic and trimorphic females are found in very many species.

IV. Conclusions.

In the moth *Thyreus abbotii*, the most aberrant dimension of the fore wing is likewise the most variable. This accords with Darwin's law.

The females show, in general, a greater degree of variability than the males; but in the one markedly aberrant feature under discussion, their variability is less than that of the males. I submit the following hypothesis to explain the smaller variability of the sinuous margin in the females. The fact that the wing broadens so greatly toward the tip, and is provided with an irregular edge, suggests that this form of margin may be of advantage in rendering the insect less distinctly visible when its wings are in rapid motion. This idea is upheld by the fact that a related species, *Amphion nessus* Cramer, has the same effect produced in color where irregularity of form is wanting. If this hypothesis be admitted, then we must look for a better development of the protective feature in the female than in the male, since the female, when burdened with eggs, cannot fly as rapidly as her mate. The sinuous margin being of less importance, comparatively, for the male, we can understand its greater variability in that sex, where it is less rigidly selected.

The work which I have here described was performed in connection with my studies under Dr. Charles B. Davenport, at Harvard University, in 1896–97. I am indebted to him for valuable suggestions and advice.

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